Force and Motion

PMRehan

For watsapp only please click here ☞ KPK, Mardan, Katlang.

- Every physical process involves some motion. We live in universe of continual perpetual motion. Where every piece of matter is in motion.
- *Mechanics* → deals with study of motion of body.
- Mechanics are of two kinds:
  1. *Classical mechanics* → macro-level.
  2. *Quantum mechanics* → micro-level.

Kinematics;	**Dynamics;**
Study of motion without their cause.	Study of motion with reference to its cause and types.

- Rest and motion depends on observer.

Two friends in the uniform moving train are at rest to each other while at motion for the observer at ground.

Motion may be Translational, rotational or vibrational.

There is no absolute rest or motion.

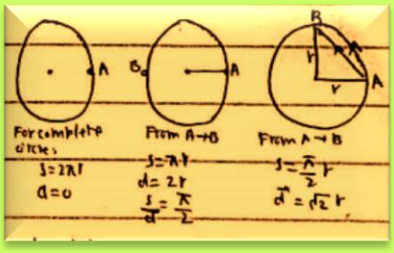
Displacement;

- Shortest distance b/w two positions.
- Vector quantity, Dir: in the direction of motion, unit is Meter, Dim =$[L]$.
- Denoted by Δx, Δr, Δl and Δd.
- Straight path OR *Rectilinear motion* → displacement = distance.
- For 90°, Phytagrouse theorem gives us the displacement.
- Circular motion → Disp = zero, so for 1rev disp = 0.

By PMRehan

- $\frac{Displacement}{Distance} \leq 1$ while $Distance/_{Displacement} \geq 1$.
- For 1rev → $\frac{dist}{disp} = \infty$ while $\frac{disp}{dist} = 0$.
- For semi-circular path i.e. $\frac{1}{2}rev$ → disp = diameter = 2r while dist = πr = $\frac{2\pi r}{2}$.

- For semi-circular path → $\frac{dist}{disp} = {}^{\pi}/_{2} > 1$.
- Disp of body may be zero but distance never, disp > dist is never possible.
- For quarter and $\frac{3}{4}$ of rev → displacement is same i.e. $r\sqrt{2}$.
- For quarter rev → dist = $\frac{2\pi r}{4}$ and $\frac{disp}{dist} = \frac{2\sqrt{2}}{\pi}$.
- Distance, $S = Vt$. Or $S = V_i t + \frac{1}{2}at^2$.
- ***Distance*** is the actual path travelled by the body b/w two points.



- Distance is scalar.
- Distance never be -ive.

Translatory motion → motion in which every particle of body move parallel to each other with equal speed.

Rotatory motion → motion of all particles around fix point.

Vibratory motion → to and fro.

Velocity;

- Time rate of change of displacement is called ……..
- Measure of displacement (Δd) with passage of time (Δt) is called ……..
- Vector quantity, Dir; in the direction of displacement.
- $\Delta v = \frac{\Delta d}{\Delta t} = \frac{d_f - d_i}{t_f - t_i}$ Unit = ${}^{m}/_{S}$ in C.G.S = $\frac{cm}{s}$. Dim = $[LT^{-1}]$.

$$\frac{Km}{h} = \frac{5}{18} m/s$$

- $\vec{V} = V\hat{V}$. Here the simple V i.e. mag of velocity is called ***speed***.
- Velocity gives more information than speed.
- $\frac{Speed}{Velocity} \geq 1$ b/c $\frac{\frac{S}{t}}{\frac{d}{t}} = \frac{S}{d}$.
- For moving body → $S \neq 0$, $V \neq 0$ But $\vec{V} \geq 0$.
- In circular motion, mag of velocity is constant. So speed will be uniform and velocity variable.

By P M Rehan

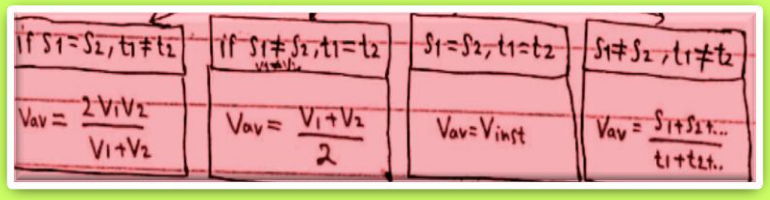
Average velocity;

- Total displacement divided by total time taken in non-uniform motion.
- $\langle\vec{V}\rangle = \frac{Total\ disp}{Total\ time\ taken}$, $\langle\vec{V}\rangle = \frac{\vec{d}}{t}$.
- It doesn't tell us that motion is steady OR variable, path is straight or curved.

Average speed and cases;

Case#1;	Case#2;	Case#3;
→Time duration same. →Covered distance S_1 with speed V_1 and S_2 with V_2. → $S_1 \neq S_2$ & $t_1 = t_2 = t$. → $V_{AV} = \frac{S_1+S_2}{t_1+t_2}$. → $V_{AV} = \frac{S_1+S_2}{\langle\frac{S_1}{V_1}+\frac{S_2}{V_2}\rangle}$. → $V_{AV} = \frac{V_1V_2(S_1+S_2)}{S_1V_2+S_2V_1}$.	→for same distance travelled. →first half is covered with V_1 @ time t_1 and the other half with V_2 with t_2. → $S_1 = S_2 = S$. → $V_{AV} = \frac{S_1+S_2}{V_1+V_2}$. → $V_{AV} = \frac{S+S}{\left(\frac{S}{V_1}+\frac{S}{V_2}\right)}$. → $V_{AV} = \frac{2(V_1V_2)}{V_1+V_2}$.	→for same distance travelled. →the 1st $\frac{1}{3}$ is covered with V_1, the 2nd $\frac{1}{3}$ is covered with V_2 and the next $\frac{1}{3}$ with V_3. → $V_{AV} = \frac{3(V_1V_2V_3)}{V_1V_2+V_2V_3+V_1V_3}$.

Uniform speed and velocity;



- When same displacement is covered in equal time interval.
- **Uniform speed** → when same dist is covered in equal time interval.
- **Uniform motion** → motion with constant velocity. Possible only in straight line.
- Uniform motion → dist = disp, speed = velocity (in mag only) and also average and instantaneous speed OR velocity are equal.
- In uniform velocity the $S_1 = S_2$, $t_1 = t_2$.

Time taken by light from sun to earth is 500sec i.e. 8min.20sec.
Uniform circular motion → velocity is variable but speed is constant.

Instantaneous velocity;

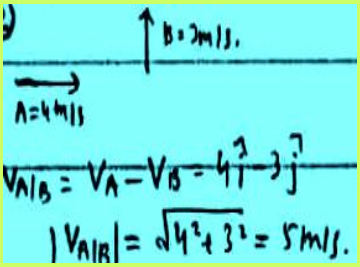
By P M Rehan

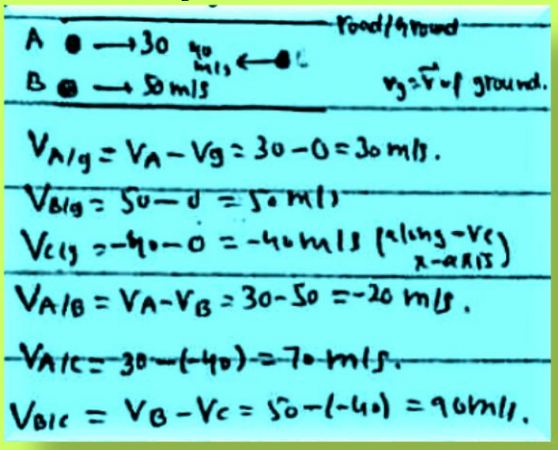
- The velocity at particular instant of time. The time interval is very short that approach to zero.
- $\vec{V} = Lim_{\Delta t \to 0} = \frac{\Delta d}{\Delta t}$.
- Speed meter of a car gives information about the instantaneous speed.

→Slope of disp—time graph = velocity.
→Slope of dist—time graph = speed.
→Slope of graph/G
radient = Tanθ.
→Slope of $\vec{d}$—t graph b/w two points gives us $\vec{V}_{AV}$ while slope of the tangent in $\vec{d}$—t gives instantaneous velocity.
→Speed can never be –ive.

Relative velocity;

- Velocity of object w.r.t another object.
- 1 → Both move towards or away from each other; (Dir: not same)
  $V_{rel} = V_A + V_B$.
- 2 → Both move in d/f direction:
  $V_{rel} = V_A - V_B$.
- In general all thee velocities in universe are relative except Speed Of Light.
- A = 60° B = 30° → relative velocity of A with B = $\frac{V_A}{V_B} = \frac{tan\theta A}{tan\theta B}$ => 3 : 1.
- Two photon moving in opp direction, the relative velocity will be 2C but speed higher than light is not possible so it is C.
- Relative velocity of body with itself is equal to zero.




Road/ground
A → 30 m/s, ←
B → 50 m/s
$v_g = \vec{v}$ of ground.
$V_{A/g} = V_A - V_g = 30 - 0 = 30 m/s.$
$V_{B/g} = 50 - 0 = 50 m/s$
$V_{c/g} = -40 - 0 = -40 m/s$ (along -ve x-axis)
$V_{A/B} = V_A - V_B = 30 - 50 = -20 m/s.$
$V_{A/C} = 30 - (-40) = 70 m/s.$
$V_{B/C} = V_B - V_C = 50 - (-40) = 90 m/s.$

Acceleration;

- Time rate of change of velocity. But there is no physical quantity to measure rate of change of acceleration (Δa).
- Vector quantity, unit = ms^{-2}, $\vec{a} = \frac{\Delta V}{\Delta t} => \frac{V_f - V_i}{t_f - t_i}$, Dim =$[LT^{-2}]$.
- Change in velocity may be in direction or magnitude.
- It is measure of how rapidly velocity is changing.
- In circular motion, speed may be constant but velocity can't b/c direction change.

By P M Rehan

- ***Average acceleration*** → $\langle \vec{a} \rangle = \frac{total\ change\ in\ velocity}{total\ time}$.
- ***Instantaneous acceleration*** → $\vec{a} = \lim_{\Delta t \to 0} \frac{\Delta V}{\Delta t}$.
- ***Uniform acceleration*** → *no jerk, velocity changes is equal in equal interval of time.*
- ***Variable acceleration*** → *when unequal change in velocity in equal interval of time.*

→Shake is the unit of time:
→1shake = 10^{-8}sec.
$\frac{A^{\circ}}{shake}$ = speed.
→In circular motion, the θ in $\vec{a}$ and $\vec{V}$ is 90°.
C.G.S → centimeter, gram and sec. Used in france.

- ***Deceleration/retardation*** → *when object is slowing down OR when magnitude of velocity is decreasing. The* $\vec{V}$ ***and*** $\vec{a}$ ***are in opp direction.***
- *When object is speeding up* $\vec{a}$ ***= +ive →*** $\vec{a}$ **II** $\vec{V}$, ***when slowing down*** $\vec{a}$ ***= -ive →*** $\vec{a}$ ↑↓ $\vec{V}$.
- *+ive* $\vec{a}$ → $V_f > V_i$, $\frac{V_f}{V_i} > 1$. $\vec{a} \propto \Delta V$.

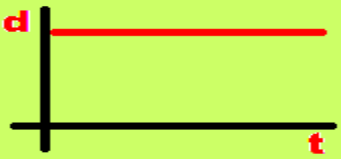
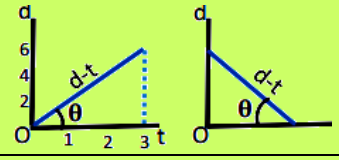
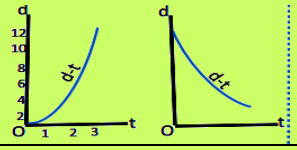
By P M Rehan

Graphical analysis

- Graph → showing relationship b/w physical quantities by using co-ordinate system.

Displacement—Time graph;

- The slope of Displacement—Time graph = Velocity. Disp can be -ive so slope may also be -ive.
- Disp on y-axis and time on x-axis.

Time is passing and no change in Δdisp = 0, $\Delta V = 0$. So the body is at rest. 	Disp increase uniformly with time, slope is constant. Object move with uniform velocity. 	Disp change non-uniformly with time, slope is changing. The body move with variable velocity. 

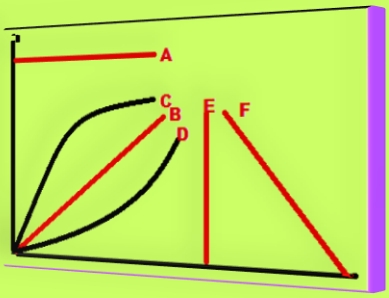
- Distance—time graph slope = speed while area under distance—time graph = nothing.
- Rectilinear motion → speed = velocity.

Velocity—Time graph;

A. Constant velocity, $\vec{a} = 0$.

B. Uniform velocity, $\vec{a} \neq 0$ **but constant.**

C. Slope decrease with time, so $\vec{a}$ **also also decrease.**



By P M Rehan

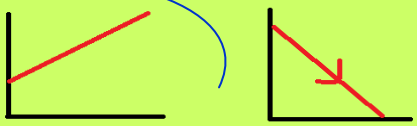
D. Slope increase with time, so $\vec{a}$ **also also increase.**

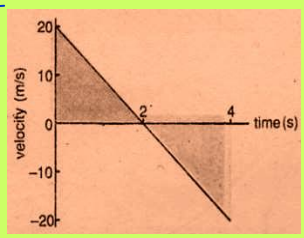
E. Infinite acceleration → not possible.

F. Show uniform retardation.

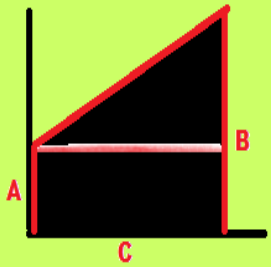
Non-uniform circular motion both the mag and direction of velocity changes, so two components of velocity are considered: one is perpendicular and one is parallel OR anti-parallel to velocity.

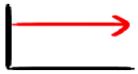
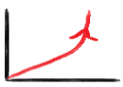
- The case C and D represent the variable acceleration.
- Velocity—Time graph for the ball thrown upward:
- when initial velocity > 0.
- Acalaration—time graph gives us speed.





- The line start from origin when V_i=O.
- Area in the figure is trapezium which is equal to $\frac{1}{2}(A+B)\,C$.

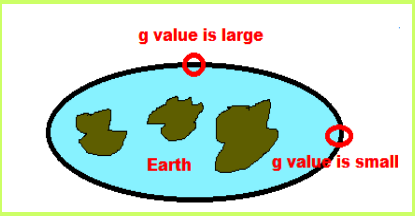


Graph;	Displacement;	Velocity;	Acceleration;
	$\Delta d = 0$	**0**	**0**
	Increase uniformly	**+ive, uniform,** $\Delta V = 0$	**0**
	**Increase non-uniformly**	**+ive, Increase non-uniformly**	$+\vec{a} \neq 0$

By P M Rehan

EQUATION OF MOTION

- The three equations are applicable for uniform acceleration only. These are kinetic equation i.e. no involvement of force.
- $S = V_{AV} \times t \Rightarrow S = \frac{V_f + V_i}{2} \times 2 \Rightarrow V_f = V_i + at \rightarrow (1st\ eq\ of\ motion)$.
- $S = V_i t + \frac{1}{2}at^2 \rightarrow (2nd\ eq\ of\ motion)$.
- $2aS = V_f^2 - V_i^2 \rightarrow (3rd\ equation\ of\ motion)$.



$V_f = V_i + at$	$V_f = V_i + gt$
$S = V_i t + \frac{1}{2}at^2$	$S = V_i t + \frac{1}{2}gt^2$
$2aS = V_f^2 - V_i^2$	$2gS = V_f^2 - V_i^2$

Free fall motion;

- $V_i = 0,\ V_f = gt,\ h = \frac{1}{2}gt^2 \Rightarrow 5t^2,\ V_f = \sqrt{2gh}$ (Velocity to reach the ground).
- Time to reach the ground $t = \sqrt{\frac{gh}{2}} \Rightarrow \sqrt{\frac{h}{5}}$.
- Distance covered by free fall body in 1st second = 5m.
- Distance covered in 2nd second = $\frac{1}{2}g(2^2)$.
- Distance covered in 3rd second = $\frac{1}{2}g(3^2)$.
- The ratio is 1:4:9.
- Distance coverd by a body in nth second when initial velocity (may be 0) is given $S_{nth} = V_i + \frac{a}{2}(2n-1)$ and for free fall: $S_{nth} = V_i + \frac{g}{2}(2n-1)$.

Object fall from height of 5m, the velocity at the time of hitting the ground:

$V_f = \sqrt{2\,(10)(5)} = 10\,\frac{m}{s}$.

For objects moving upward freely

$a \uparrow\downarrow v_i$

$a = -g$

$v_f = v_i - gt$

$S = v_i t - \frac{1}{2}gt^2$

$-2gS = v_f^2 - v_i^2$

- $g \rightarrow$ always directed towards center of the earth, for upwards motion it is taken $g = -g$ and downwards $g = g$.
- in absence of air, all bodies fall with same acceleration towards earth called gravitational acceleration.

By P M Rehan

- $g \propto \frac{1}{R^2}$, at center of earth g = 0, maximum at poles while minimum at equaters.
- Upto 1Km from earth surface the value of g remain unchanged.

Moving from surface to depth towards center;

- $\acute{g} = g\left[1 - \frac{d}{R}\right]$ here d represent the distance and R represent the radius of earth.
- When $d = \frac{R}{2}$ than $\acute{g} = \frac{g}{2}$ but when d = R than $\acute{g} = 0$ (at center).

Moving upward from earth surface;

- $\acute{g} = g\left[\frac{1}{(R+d)^2}\right]$ here d represent the height from earth surface.
- When $d = \frac{R}{2}$ than $\acute{g} = \frac{4}{9}g$ and if d = R than $\acute{g} = \frac{1}{4}g$.

Value of g at moon $g_m = \frac{g_e}{6}$= 1.6.
When body thrown upward:
Max height = $\frac{V_i^2}{2g}$.
Time to reach max height = $\frac{V_i}{g}$.
Time to hit ground = $2 \times \frac{V_i}{g}$.
Speed with which hit ground = V_i

Value of g also changed at earth surface due to oval shape of earth

A man thrown one ball and one down with same initial velocity, both the ball will hit the ground at same speed.

By P M Rehan

Newton's Laws of Motion

- Empirical laws, obeyed at low speed. **Published in book Principia.**

First law of motion;

- An object remains at rest or uniform motion unless it is compelled to change by an unbalanced force.
- This law is also called ***Law Of Inertia***. This law provides def of force (qualitative) and inertia.
- Velocity of body ever remains constant in absence of force on it.
- If $\vec{F}_{net} = 0$, $\vec{a} = 0$ but velocity may be zero OR uniform.
- Property (having no unit) of alls body that resist acceleration is called Inertia. Opposition offered by a body to change in its state.
- **Mass of body is direct measure of inertia.**
- This law is obeyed in inertial frame of reference i.e. $\vec{a} = 0$.
- Inertia is not depend upon velocity.

The agent which cause change in state of the body is called Force.

At rest inertia = mass while at motion inertia = momentum

2nd law of motion;

- Force acts on body produce acceleration, this $\vec{a}$ is directly proportional to mass and inversely to mass.
- $\vec{a} \propto F, \vec{a} \propto 1/m$ => $\vec{a} \propto \frac{F}{m}$ => $F = m\vec{a}$.
- $m_1\vec{a}_1 = m_2\vec{a}_2$ OR $\frac{F_1}{F_2} = \frac{\vec{a}_1}{\vec{a}_2} = \frac{m_2}{m_1}$.
- Slug = 14.54Kg.
- At 0° push and pull is same but at 30° push is easier.

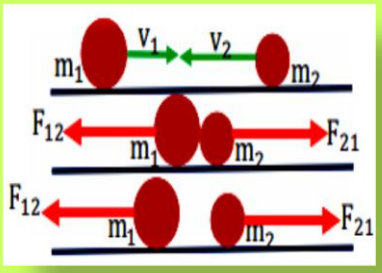
This law measure force and also called Law Of Acceleration.
Unit of force →newton = Kgms^{-2}, 1N = 10^5dyne (C.G.S).
Direction of acceleration = in the direction of net force.

3rd law of motion;

- For an action there is always reaction, same in mag but opposite in direction.
- Force will be same but acceleration not.

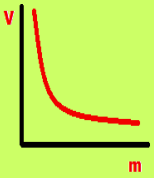
By P M Rehan

- Action and reaction occurs in pair so can't neutralize each other. Equal forces neutralize each other when act on single object.



Momentum

- Quantity of motion possessed by a body. Product of mass and velocity.
- $\vec{P} = m\vec{V}$, Unit → Kgm/s OR Ns, vector quantity, Dim: = $[MLT^{-1}]$.
- Dir: in the direction of velocity.
- Momentum of particle → $\vec{P} = \frac{h}{\lambda}$ and that of photon = $\vec{P} = \frac{h}{c}$.
- **Time rate of change of linear momentum → Force while Time rate of change angular momentum → Torque.**
- Free fall body → $mg = \frac{\Delta P}{\Delta t}$.
- K.E = $\frac{P^2}{2m}$ => $P = \sqrt{2m(K.E)}$.
- Slope of momentum time graph = force.



Newton 2nd law and momentum;

F = ma => $m\left(\frac{\Delta V}{\Delta t}\right)$.

=> $m\left(\frac{V_f - V_i}{\Delta t}\right)$ => $\left(\frac{mV_f - mV_i}{\Delta t}\right)$.

=> $\left(\frac{P_f - P_i}{\Delta t}\right)$ => $\left(\frac{\Delta P}{\Delta t}\right)$.

Force → Time rate of change of momentum.

Slope of momentum—time graph = force.

Impulse

- When large force act on body for very short time than product of that force and time is called impulse.
- $\vec{I} = \vec{F} \times \Delta t$. $\vec{I} = \Delta P$. $\vec{I} = mV_f - mV_i$.
- Dir: along the direction of force. Vector quantity, unit → Ns. Dim: $[MLT^{-1}]$
- When $\vec{V}$ is constant, $\Delta\vec{V} = 0, \Delta\vec{P} = m\Delta\vec{V} = 0$ than $\vec{I} = 0$.
- $\vec{I} \neq 0$ when velocity is variable.
- Impulse cases mostly seen during collision.

By P M Rehan

Law of conservation of momentum;

- Total linear momentum of an isolated system remains constant.
- Initial momentum = final momentum.

  $m_1V_1 + m_2V_2 = m_1V_1 + \acute{m}_2\acute{V}_2$.
- mV =constant.
- Isolated system → involvement of no external force.

$$MV = -m_1v_1' + m_2v_2'$$

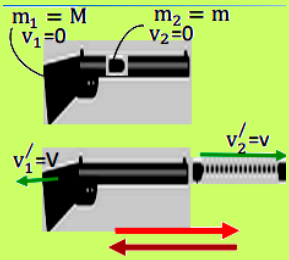
$$0 = -m_1v_1' + m_2v_2'$$

$$\frac{v_1'}{v_2'} = \frac{m_2}{m_1}$$

$$K.E = \frac{P^2}{2m}$$

$$K.E \propto \frac{1}{m}$$

$$\frac{K.E_1}{K.E_2} = \frac{m_2}{m_1}$$

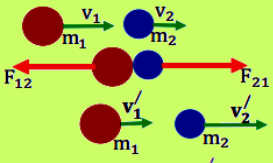


$$m_1v_1 + m_2v_2 = -m_1v_1' + m_2v_2'$$

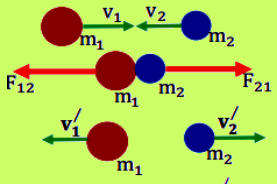
$$M(0) + m(0) = -MV + mv$$

$$0 = -MV + mv$$

$$V = \frac{m}{M}v$$



$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

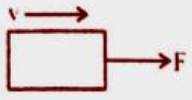
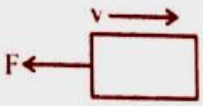
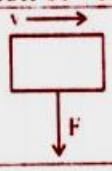


$$m_1v_1 - m_2v_2 = -m_1v_1' + m_2v_2'$$

By P M Rehan

Extra points

- Increase in slope cause increase in speed and vice versa.
- The force with which the body is attracted towards earth center → Weight.

When force acts in direction of velocity	When force acts opposite to direction of velocity	When force acts perpendicular to direction of velocity	When force acts at some angle to the direction of velocity
			
Speed increases and direction of motion remain same	Speed decreases and direction of motion remain same	Only direction changes and magnitude of velocity remain same	Both magnitude and direction of velocity changes

- when a force acts on the body then reaction act normally to the surface of body.
- The idea of momentum was introduced by Newton.
- **Frame of Reference:** It is a system to which a set of coordinates are attached and with reference to which observer describes any event.

One dimensional	Two dimensional	Three dimensional
Motion of a body in a straight line is called one dimensional motion.	Motion of body in a plane is called two dimensional motion.	Motion of body in a space is called three dimensional motion.
When only one coordinate of the position of a body changes with time then it is said to be moving one dimensionally	When two coordinates of the position of a body changes with time then it is said to be moving two dimensionally.	When all three coordinates of the position of a body changes with time then it is said to be moving three dimensionally.
Ex.. (i) Motion of car on a straight road. (ii) Motion of freely falling body.	Ex. (i) Motion of car on a circular turn. (ii) Motion of billiards ball.	Ex.. (i) Motion of flying kite. (ii) Motion of flying insect.

By P M Rehan

- The smallest part of matter with zero dimension which can be described by its mass and position is defined as a **particle or point mass**.
- If the size of a body is negligible in comparison to its range of motion then that body is known as **a particle**.
- A body (Group of particles) can be treated as a particle, depends upon types of motion. For example in a planetary motion around the sun the different planets can be presumed to be the particles.
- In above consideration when we treat body as particle, all parts of the body undergo same displacement and have same velocity and acceleration.
- For motion between two points, displacement is single valued while distance depends on actual path and so can have many values.
- For a moving particle distance can never decrease with time while displacement can. Decrease in displacement with time means body is moving towards the initial position.
- The instantaneous speed is average speed for infinitesimally small time interval (*i.e.*, $\Delta t \to 0$).
- A particle may have constant instantaneous speed but variable instantaneous velocity.
- *Example:* When a particle is performing uniform circular motion then for every instant of its circular motion its speed remains constant but velocity changes at every instant.
- Instantaneous velocity is always tangential to the path followed by the particle.
- The magnitude of instantaneous velocity is equal to the instantaneous speed.
- For a given time interval average velocity is single valued while average speed can have many values depending on path followed.
- Dir of acceleration = dir of change in velocity (not velocity).

When only direction of velocity changes	When only magnitude of velocity changes	When both magnitude and direction of velocity changes
Acceleration perpendicular to velocity	Acceleration parallel or anti-parallel to velocity	Acceleration has two components one is perpendicular to velocity

By P M Rehan

		and another parallel or anti-parallel to velocity
Ex·· Uniform circular motion	Ex·· Motion under gravity	Ex·· Projectile motion

- Acceleration is said to be constant when both the magnitude and direction of acceleration remain constant·
- This motion of a body falling towards the earth from a small altitude ($h << R$) is called **free fall**·
- In case of motion under gravity, time taken to go up is equal to the time taken to fall down through the same distance· Time of descent = time of ascent·
- In case of motion under gravity, the speed with which a body is projected up is equal to the speed with which it comes back to the point of projection· As well as the magnitude of velocity at any point on the path is same whether the body is moving in upwards or downward direction·
- A body is thrown vertically upwards· If air resistance is to be taken into account, then the time of ascent is less than the time of descent·
- For one dimensional motion the angle between acceleration and velocity is either 0° or 180° and it does not change with time·
- If the angle between $\vec{a}$ and $\vec{V}$ is 90°, the path of the particle is a circle·
- Greater the slope of displacement-time graph, greater is the velocity and vice-versa·
- The body returns to its point of projection with the same magnitude of the velocity with which it was thrown vertically upward, provided air resistance is neglected·
- The speed of the body on return to the ground = speed with which it was thrown upwards·

This notes will be more updated INSH-A-ALLAH and the collision and projectile motion will be available in the 2nd part of this notes!!!!!!!

Regard: KeEp In YoUrS pRaYeRs....

By P M Rehan